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EFFECTS OF TIME OF PLANTING AND OF FERTILIZER MIXTURES ON THE CURLY-TOP RESISTANT SUGAR-BEET VARIETY U.S. NO. 1 IN IDAHO

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INTRODUCTION

A variety of sugar beets resistant to the curly-top disease has been developed by the Division of Sugar Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture, and when released will be known as the U.S. No. 1 variety. The performance of this variety under varying degrees of curly-top exposure is discussed in a bulletin prepared by Carsner and others (*2*),[1] and results obtained from many comparison plantings made in a large number of localities in five different States show that under the conditions of the test the U.S. No. 1 variety outyielded by approximately 4½ tons of beets per acre the commercial brand used as a check.

In anticipation of the advantageous utilization of this curly-top resistant sugar-beet variety in planting much sugar-beet acreage in the affected areas, the question was raised as to the additional increases likely to result when certain favorable cultural practices were used with this variety. To determine the responses to special treatment, investigations were undertaken in 1931 in the Idaho area. This circular deals with two cultural practices to determine: (1) The influence of time of planting on the U.S. No. 1 variety and on the commercial brand used for comparison, and (2) the response to fertilizer of the U.S. No. 1 variety under curly-top conditions.

The subject of the application of commercial fertilizer to various crops has received considerable attention abroad (*9*), and much has been published concerning the use of fertilizer. In the United States some of the State experiment stations and beet-sugar companies have for many years studied the use of commercial fertilizer, but it is only within recent years that results have been obtained that have led to their commercial utilization.

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[1] Italic numbers in parentheses refer to Literature Cited, p. 16.

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Apparently more precise methods of evaluating the fertilizer requirements of the sugar-beet crop were needed in order to determine the commercial fertilizers to be recommended for different soil types. The investigations of the Division of Soil Fertility, Bureau of Chemistry and Soils, United States Department of Agriculture, cooperatively undertaken in the Arkansas Valley of Colorado (*10*), take precedence in this regard, by reason of specific work done on the commercial-fertilizer requirements of the sugar-beet crop, based on definite comparisons of plant food applied. Inasmuch as this initial work was based on the triangle system for fertilizer experiments, which was followed in making the tests reported in this circular, a brief discussion is given of the principles involved.

FERTILIZER TRIANGLE

The triangle system for fertilizer experiments (*8*) originated with a study of nutrient solutions (*7*). After this method had been used in plant physiological investigations it was successfully applied to field studies, first in 1913 (*5*) in a grass experiment conducted by the Office of Soil Fertility Investigations, Bureau of Soils, in cooperation with the Pennsylvania Agricultural Experiment Station, and later with many other crops in various localities in connection with fertilizer problems. For a discussion of the results on these various crops, the reader is referred to the paper presented by Schreiner (*6*) before the National Fertilizer Association in 1930 and to the published reports and bulletins of the Division of Soil Fertility, Bureau of Chemistry and Soils.

In discussing the use of the triangular diagram and the method of interpreting the results (*5*), the authors state:

> The [fertilizer] triangle therefore represents single fertilizer constituents at the apices or vertices, mixture of any two constituents along the boundary lines of the triangle, and mixtures of all three constituents within the triangle. * * * The regular gradation in the composition of fertilizer used on adjoining plats makes it possible in this scheme to consider not only the individual plats but groupings of any number of adjoining plats. In this way the result of any individual plat is supported by the results on the neighboring plats which vary but slightly from it in composition. The triangle as a whole can be used to answer the question of the effect of fertilizers in general on the land under study by comparison with the unfertilized check plats. To study the effectiveness of any particular fertilizer * * * it is possible to proceed in several ways.
>
> 1. To compare plats receiving only the single fertilizer elements with each other and with check plats * * *.
> 2. To compare the series of plats, not receiving the particular fertilizer element, with the series of plats which receive this element in increasing amounts * * *.
> 3. To compare the series receiving a given amount of nitrate with the series containing the same amount of phosphate or potash * * *.
> 4. To compare all the mainly nitrogenous plats with the mainly potassic and the mainly phosphatic plats, that is [treatments 1, 2, 3, 4, 5, and 6 (see fig. 1) in the nitrogen end of the triangle, in which the fertilizer mixture contains 50 per cent or more of nitrogen; the phosphate group of the triangle, i. e., treatments 7, 11, 12, 16, 17, and 18, in which the fertilizer mixture contains 50 per cent or more of phosphoric acid; and the potash group in the triangle, i.e., treatments 10, 14, 15, 19, 20, and 21, in which the fertilizer mixture contains 50 per cent or more of potash as compared to the inner group of plots within the subtriangle] in which no fertilizer largely predominates.
> 5. To compare the yields of plats receiving a constant amount of one of the fertilizers and varying amounts of the other two. * * *
>
> By the comparison in groups a more accurate impression of a general tendency can be obtained than by the direct comparison of individual plats. Accidental irregularities are thus almost entirely eliminated. Seasonal differences in the

yields from year to year, involving the possibility that any one of the fertilizer ingredients is becoming either more or less effective in the course of time, can also be ascertained by this method of comparing the results. * * *

The use of commercial fertilizer in commercial sugar-beet growing is rapidly increasing, and in some of the areas where research data are lacking the results obtained are frequently of an apparently contradictory nature because of lack of proper approach to the problem involved. This condition is being remedied where critical studies on commercial-fertilizer evaluation can be undertaken. The information presented in this circular applies to the Idaho area.

DATE-OF-PLANTING TEST WITH APPLICATION OF PHOSPHATE

CONDITIONS OF TEST

In the experimental work conducted in the Twin Falls, Idaho, district in 1931 on the evaluation of the curly-top resistant U.S. No. 1 variety as influenced by time of planting and application of commercial fertilizers, it was decided to carry out the tests on the experimental farm[2] near Castleford, Idaho. This district is near the breeding grounds of the beet leaf hopper (*Eutettix tenellus* Baker), which, as the vector of the curly-top virus, has been responsible for severe reduction in beet yields. There was an example of such reduction in 1931, when in the Twin Falls district in the Idaho area an average yield of 7.13 tons of sugar beets was produced on a greatly reduced acreage (1,061 acres harvested), whereas in a favorable year such as 1927 (a year of little curly-top damage) an average of 16.35 tons of sugar beets was produced on 4,887 acres. The soils in this district are the Portneuf series, mostly of the silt-loam type (*1*) and primarily its shallow phase. These soils are of wind-borne or loessial origin. The surface soils of this series are light brown to brown, overlying a compact, highly calcareous, light grayish-brown upper subsoil and a loose floury deeper stratum. This in turn is underlain by basaltic bedrock. The silt-loam type is a very important agricultural soil; it covers the greater part of the irrigated area of the Twin Falls district and usually produces large yields of a variety of crops.

A soil test according to the Winogradsky method, as reported by Guittonneau (*4*), to determine whether an application of phosphate was necessary for the production of a crop of beets, had been made by the chemists of the local sugar company. The grade "fair" (indicating a fair supply of phosphate) was recorded for the sample of soil obtained from the portion of the field where the date-of-planting tests were made, in which the application of treble superphosphate gave no response. The grade "trace" (indicating an inadequate supply of phosphate) was recorded for that portion of the field where the intensive test of the 21 commercial fertilizer mixtures was made, in which a decided crop response was obtained from the application of commercial fertilizer.

For at least 6 years no manure had been applied to the soil where the two projects were located. In 1929 the field was fall plowed and the portion of the field where the 1931 dates of planting occurred was fallowed from July 1930 until the fall, when the field was again fall plowed. The portion of the field devoted to the fertilizer work in 1931 had been cropped to Mexican beans in 1930 and a large crop had been produced. This field was spring plowed in 1931. These conditions are set forth at this time as a possible explanation for the failure to obtain an increase in yields by the application of phosphate in the time-of-planting series, while in another portion of the field, which had been under different conditions of cropping and soil handling, an appreciable response was obtained from application of commercial fertilizers. This condition is frequently met in farmers' fields, where an application of commercial fertilizer (at present chiefly superphosphate) produces appreciable tonnage increases in one field, while in a closely adjoining field, or often in a portion of the same field, no appreciable benefits can be noted.

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[2] The experimental work in the Castleford, Idaho, district is being carried on in cooperation with the Amalgamated Sugar Co., which has provided land and other facilities for the tests.

In the study of the influence of time of planting and of the application of 100 pounds of treble superphosphate fertilizer at the time of planting upon the performance of the U.S. No. 1 variety and that of a commercial brand (Old Type), nine plots were arranged in a Latin square; the variables were distributed in the following manner:

Variable		Plot arrangement
(1) Old Type, planted Apr. 6		5 4 8 2 3 1 6 7 9
(2) Old Type, planted Apr. 28		2 1 6 5 9 8 7 3 4
(3) Old Type, planted May 8		8 2 9 3 6 4 1 5 7
(4) U.S. No. 1, planted Apr. 6		9 3 1 4 7 5 2 6 8
(5) U.S. No. 1, planted Apr. 28		6 5 3 8 2 7 9 4 1
(6) U.S. No. 1, planted May 8		1 6 4 7 5 2 8 9 3
(7) U.S. No. 1, planted Apr. 6	100 pounds of treble superphosphate fertilizer per acre applied with seed	3 7 2 6 1 9 4 8 5
(8) U.S. No. 1, planted Apr. 28		7 8 5 9 4 6 3 1 2
(9) U.S. No. 1, planted May 8		4 9 7 1 8 3 5 2 6

On the dates indicated, the seed was planted at the rate of 23 pounds per acre in plots, each $\frac{1}{77.65}$ of an acre in area and consisting of 8 rows 22 inches apart, replicated 9 times in restricted random arrangement. Good initial stands of beets were secured on all the plots, especially on those planted early and at an intermediate date. No visual differences in foliage or in root development were observed, during the growing season or at harvest time, between the fertilized and the unfertilized U.S. No. 1 series. The inner 6 rows of each plot were harvested on October 15, on a normally competitive-beet basis,[3] and the data were computed on the basis of a 100 percent stand of beets.

Determinations of sucrose and coefficient of apparent purity were made from three 20-beet samples of normally competitive beets. These beets were put in moisture-proof sacks and taken to the laboratory, where they were washed, weighed, and analyzed. The sucrose in the beet was determined by the Sachs-Le Docte cold-water digestion method. Purity was determined by direct reading of the Brix of the expressed juice and direct determination, with the polariscope, of the sucrose in the clarified undiluted juice.

EXPERIMENTAL DATA

YIELD

For both the fertilized and the unfertilized plots planted to the U.S. No. 1 variety the yields in tons of beets per acre (table 1) showed significant differences, according to the z test,[4] in favor of the early date of planting. The yield from early planted plots is generally much larger than that from plots planted at an intermediate date; but in 1931, because the planting season in the Idaho area was somewhat backward, it was not possible to plant as early as desired. There were appreciable but not significant differences in yield between the plots planted at an intermediate date and those planted later. There were no appreciable differences in yield between the fertilized and the unfertilized plots planted to the U.S. No. 1 variety on the same date.

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[3] By a "normally competitive beet" is meant a beet which has grown surrounded on all four sides by beets at approximately the right distance to conform to the requirements of the test. The average weight per beet, computed from the competitive-beet samples, multiplied by the appropriate number of beets per acre (in this case 23,760) has given the yield on the basis of a 100 percent stand under the conditions of this test.

TABLE 1.—*Effect on commercial brand (Old Type) of time of planting and effect on U.S. No. 1 sugar-beet variety of time of planting and of phosphate fertilizer applied with seed, at Castleford, Idaho, in 1931*

[Data represent averages of 9 plots, each $1/47.65$ of an acre in area and consisting of 8 rows 22 inches apart]

Treatment no.	Variety	Date of planting	Weight per normally competitive beet	Yield per acre	Sucrose[1]	Coefficient of apparent purity[2]	Sugar per acre	
							Gross[3]	Indicated available[4]
			Pounds	*Tons*	*Percent*		*Pounds*	*Pounds*
1	Old Type	Apr. 6	0.6439	7.649	18.42	91.95	2,818	2,591
2		Apr. 28	.6644	7.893	18.61	90.75	2,938	2,666
3		May 8	.4102	4.873	18.67	89.67	1,819	1,631
Average			.5728	6.085	18.57	90.79	2,525	2,296
4	U.S. No. 1	Apr. 6	1.2135	14.416	19.59	93.68	5,648	5,291
5		Apr. 28	1.0746	12.766	19.02	93.00	4,856	4,516
6		May 8	.9769	11.605	19.38	92.37	4,498	4,155
Average			1.0883	12.929	19.33	93.02	5,001	4,654
7		Apr. 6[5]	1.2266	14.571	18.94	92.20	5,519	5,089
8		Apr. 28[5]	1.0843	12.882	19.46	92.85	5,014	4,656
9		May 8[5]	.9713	11.539	19.34	92.11	4,463	4,111
Average			1.0941	12.997	19.25	92.39	4,999	4,619
z[6]			1.7459	1.7459	.7605	.9344	1.6462	1.8351
Standard error of mean			.0482	.5720	.1952	.5043	251	201
Standard error of difference			.0681	.8090	.2760	.7131	355	284
Difference required for significance (items 1–9)			.1362	1.618	.5520	1.426	710	568
Difference required for significance between averages[7]			.0786	.934	.32	.82	410	328

[1] Determined by the Sachs-Le Docte cold-water digestion method on three 20-beet samples of normally competitive beets per plot.

[2] Determined by direct reading of the Brix of the expressed juice and direct polariscopic determination of sucrose in the clarified undiluted juice.

[3] Obtained by multiplying yield by sucrose percentage.

[4] Obtained by multiplying gross sugar per acre by coefficient of apparent purity.

[5] 100 pounds of 45 percent treble superphosphate was applied with seed.

[6] 5 percent point for $z=0.3702$; 1 percent point$=0.5189$.

[7] Obtained from formula $2\left(\frac{\text{Standard error of mean}}{\sqrt{\text{Number of treatments compared}}}\times\sqrt{2}\right)$.

Between the unfertilized commercial brand used as a check and the U.S. No. 1 variety, whether fertilized or unfertilized, there were significant differences in yield regardless of the date of planting. Comparing the averages of the fertilized and unfertilized plots planted to the U.S. No. 1 variety, the differences were negligibly in favor of the fertilized series of plots, being 0.07 ton as compared to a required significance of 0.93 ton.

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[4] The data presented in these and succeeding tables have been analyzed according to an accepted statistical method (3) by which the general variability between blocks (randomized block) or columns and rows (Latin square) may be eliminated and a valid estimate of error obtained. In the principle of the analysis of variance the total variability is measured in sums of squares of deviations about the mean, and certain fractions are apportioned to soil heterogeneity between blocks, columns, or rows, others to treatment or varietal effect, and the balance to unknown causes, ascribed as "error". The value of z is used as a convenient measure of the significance of the test for the attribute measured; z is one half the difference between the natural or Naperian logarithms of the two mean squares being compared. Whenever the observed value of z was found to equal or exceed the value of z as calculated for either the 5 percent or the 1 percent point, indicating that the differences obtained were not due to random sampling error alone, the standard errors of the means have been computed and the differences required for significance have been determined.

SUCROSE PERCENTAGE

For sucrose percentage the results are significant. The average sucrose percentage for the unfertilized plots planted to the U.S. No. 1 variety was 19.33 and that for the plots planted to the unfertilized commercial brand was 18.57, an average difference of 0.76 percent in favor of the U.S. No. 1 variety, as compared with a required difference for significance of approximately 0.32 percent. There was practically no difference between the average sucrose percentage of the fertilized plots and that of the unfertilized plots planted to the U.S. No. 1 variety.

APPARENT PURITY

For the coefficient of apparent purity the results are significantly in favor of the plots planted to the U.S. No. 1 variety. The average purity for the unfertilized U.S. No. 1 variety was 93.02 and that for the commercial brand was 90.79, a difference of 2.23, as compared with 0.82 required for significance. There was only a slight difference in purity between the fertilized and the unfertilized U.S. No. 1 variety.

SUGAR PRODUCTION

For sugar production, in pounds per acre, the results are significantly in favor of the U.S. No. 1 variety. In pounds of gross sugar per acre the average yield for the unfertilized U.S. No. 1 variety was 5,001 pounds and that for the commercial brand was 2,525 pounds, a difference of 2,476 pounds, as compared with 410 pounds required for significance.

Analysis of these data by dates of planting shows significantly large differences in favor of the early and intermediate plantings for both the U.S. No. 1 variety and the commercial brand used as a check, as compared with the late planting for either. The average yields in pounds of gross sugar per acre of the fertilized and of the unfertilized U.S. No. 1 variety were not significantly different from each other. In pounds of indicated-available sugar per acre, the results are significantly in favor of the U.S. No. 1 variety, both fertilized and unfertilized. The average yield per acre of the unfertilized U.S. No. 1 variety was 4,654 pounds and that of the commercial brand was 2,296 pounds, a difference of 2,358 pounds, as compared with 328 pounds required for significance. There were significantly higher yields, in pounds of indicated-available sugar per acre, for the early and intermediate plantings of both the U.S. No. 1 variety, whether fertilized or unfertilized, and the commercial brand than for the late planting of either. The average yields, in pounds of indicated-available sugar per acre, for the fertilized and for the unfertilized U.S. No. 1 variety were not significantly different. This over-all increase in sugar production was primarily due to increases in beet tonnage yields, with material contribution from increases in sucrose content and the purity coefficient of the beets. The results of this test indicate that the U.S. No. 1 variety responds favorably to the influence of seasonably early planting.

FERTILIZER TESTS

MATERIALS AND METHODS

A test with 21 commercial fertilizers made up to conform to the requirements of the triangle system for fertilizer experiments (fig. 1) was conducted near Castleford, Idaho, in 1931, on a portion of the field used for the tests previously described.

This field, which was in an average state of fertility for the section considered, had good slope and was free from surface stones. The cropping history of the field was as follows: 1927 and several years previous, a mixed-grass pasture; 1928, wheat; 1929, barley; 1930, Mexican beans (good crop); 1931, experimental sugar-beet plots. In the fall of 1929 the field had been plowed to a depth of 12 inches, which was considerably deeper than any previous plowing done in this field. Considerable raw soil was brought up, but this condition did not affect the yield of the bean crop planted in 1930, which was better than the average for the district. In the spring of 1931 the field was plowed to a depth of 8 inches for the 1931 experimental beet plots. Until 1928 no manure had ever been applied to this field except by pasturage of animals.

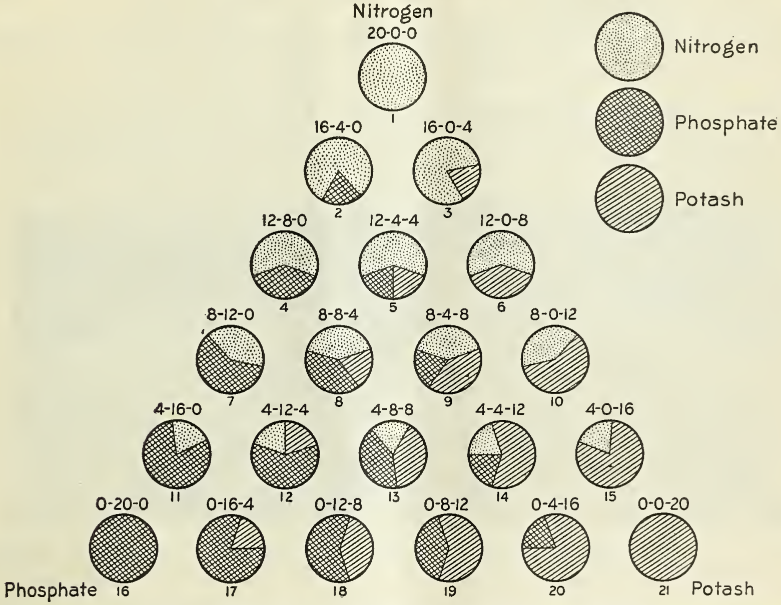

FIGURE 1.—Diagram of the triangle system of fertilizer combinations used in the experiment at Castleford, Idaho, in 1931, showing graphically the relative proportions of the three fertilizer elements in each of the 21 combinations. Each circle represents the fertilizer formula based on 20 pounds of plant food.

An excellent seed bed was prepared, and on April 6 seed of the curly-top resistant U.S. No. 1 sugar-beet variety was planted at the rate of 23 pounds of seed per acre, and fertilizer was applied with the seed (fig. 1) at the rate of 200 pounds of the various mixtures, or 40 pounds of plant food, per acre.

In this circular the values for the constituents of all fertilizer mixtures are stated in the following order: Nitrogen, phosphoric acid, and potash. The various plant-food constituents were obtained from the following sources: Nitrogen, from a mixture of equal parts of nitrate of soda and sulphate of ammonia; phosphoric acid, from superphosphate; and potash, from sulphate of potash.

The 21 different combinations of the 3 plant-food elements, nitrogen, phosphoric acid, and potash, were replicated 5 times in complete random arrangement. Each plot was $\frac{1}{161}$ of an acre in area and consisted of 4 rows 22 inches apart. Good initial stands were obtained on all plots treated with phosphate or potash and on plots fertilized with a nitrogen-bearing fertilizer containing not more than 8 percent of nitrogen.

Throughout the season marked differences were apparent in foliage growth between the fertilized and unfertilized plots, which were as striking in early July (fig. 2) as at time of harvest. The center two rows of each plot were harvested October 13. Sucrose percentage and coefficient of apparent purity were determined on three 20-beet samples of normally competitive beets. The actual yield was obtained by weighing all the beets in the two center rows.

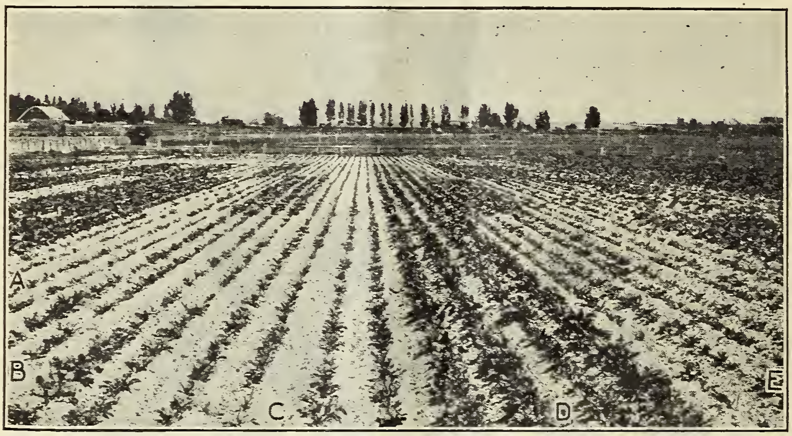

FIGURE 2.—North third of experimental field at Castleford, Idaho, July 18, 1931. A, Plot 1096, unfertilized; B, plot 1097, receiving fertilizer mixture 12–0–8; C, plot 1098, receiving fertilizer mixture 8–0–12; D, plot 1099 (large beets), receiving fertilizer mixture 4–16–0; E, plot 1100, receiving fertilizer mixture 0–0–20.

EXPERIMENTAL DATA

FINAL STAND

Table 2 shows that the effect of fertilizer treatment on stand was significant according to the *z* test. A difference between any two treatments of approximately 19 percent (i.e., 19 plants when the stand was 100 plants per 100 feet of row) was required for significance, and significant differences were shown between the effects of the higher nitrogen-bearing mixtures and those of mixtures having a high phosphoric acid or high potash content.

TABLE 2.—*Effect of fertilizer mixtures applied with seed of U.S. No. 1 sugar-beet variety, at Castleford, Idaho, in April 1931*

[Data represent averages of 5 plots, each 1/161 of an acre in area and consisting of 4 rows 22 inches apart]

Treatment no.	Plant food constituents of fertilizer mixtures [1]	Final stand	Yield		Sucrose [2]	Coefficient of apparent purity [3]	Sugar production			
			Per plot	Per acre			Gross [4]		Indicated available [5]	
							Per plot	Per acre	Per plot	Per acre
	Percent	*Percent*	*Pounds*	*Tons*	*Percent*		*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	20–0–0	36.7	66.48	5.352	19.38	91.80	12.88	2,074	11.82	1,904
2	16–4–0	53.6	95.58	7.694	19.32	92.67	18.47	2,973	17.12	2,755
3	16–0–4	44.3	56.12	4.517	18.64	93.13	10.46	1,684	9.74	1,568
4	12–8–0	68.2	108.84	8.762	19.00	93.65	20.68	3,329	19.37	3,118
5	12–4–4	66.2	106.36	8.562	19.00	94.00	20.21	3,254	19.00	3,059
6	12–0–8	57.1	62.80	5.056	18.96	92.53	11.91	1,917	11.02	1,774
7	8–12–0	72.8	123.42	9.936	18.94	94.86	23.38	3,764	22.18	3,571
8	8–8–4	78.8	117.54	9.462	19.38	93.75	22.78	3,667	21.36	3,438
9	8–4–8	77.3	113.22	9.114	19.48	94.20	22.06	3,551	20.78	3,345
10	8–0–12	62.1	71.14	5.727	19.22	94.25	13.67	2,201	12.88	2,074
11	4–16–0	84.1	133.34	10.734	19.38	93.58	25.84	4,160	24.18	3,893
12	4–12–4	90.5	139.62	11.240	19.08	94.02	26.64	4,289	25.05	4,033
13	4–8–8	95.6	141.82	11.417	19.42	94.56	27.54	4,434	26.04	4,193
14	4–4–12	75.8	129.58	10.431	19.56	94.06	25.35	4,081	23.84	3,839
15	4–0–16	72.8	85.64	6.894	19.32	93.40	16.55	2,664	15.46	2,488
16	0–20–0	82.9	138.74	11.169	19.18	94.58	26.61	4,284	25.22	4,052
17	0–16–4	82.3	143.38	11.542	19.48	94.48	27.93	4,497	26.39	4,249
18	0–12–8	86.2	146.38	11.784	19.56	94.74	28.63	4,610	27.12	4,368
19	0–8–12	87.9	135.88	10.939	19.04	94.58	25.87	4,165	24.47	3,940
20	0–4–16	87.8	127.42	10.258	19.50	93.88	24.85	4,000	23.33	3,755
21	0–0–20	81.8	98.14	7.901	19.18	95.08	18.82	3,031	17.89	2,882
	0–0–0	72.3	76.60	6.167	19.52	93.44	14.95	2,407	13.97	2,249
z [6]		.8205	.8115	.8115	(7)	(7)	.8185	.8185	.9958	.9958
Standard error of mean		6.740	13.400	1.079	.2990	.7348	2.5188	406	1.8350	295
Standard error of difference		9.530	18.950	1.525	.4228	1.0390	3.5616	574	2.5950	417
Difference required for significance		19.06	37.90	3.050	.8456	2.0780	7.1232	1,148	5.190	834

[1] Percentages of plant-food constituents of fertilizer mixtures are given in the following order: Nitrogen, phosphoric acid, and potash.

[2] Determined by the Sachs-Le Docte cold-water digestion method on three 20-beet samples of normally competitive beets.

[3] Determined by direct reading of the Brix of the expressed juice and direct polariscopic determination of the sucrose in the clarified undiluted juice.

[4] Obtained by multiplying yield by sucrose percentage and averaging individual plot values for sugar production, whence differing slightly from product of means given in this table.

[5] Obtained by multiplying gross sugar per plot or acre by coefficient of apparent purity.

[6] 5 percent point for $z=0.2564$; 1 percent point$=0.3607$.

[7] Variance due to error was greater than variance due to treatment.

For ease of comparison the treatments are so arranged in table 3 that a graph can readily be constructed (fig. 3) to demonstrate differential response to fertilizer treatment. In this figure and table the interpretation of results is based on the general mean.[5] Under such a comparison with the general mean a difference of 13.8 percent is required in order to indicate a significant difference due to fertilizer treatment (fig. 3, A). This level of significance is exceeded by treatments 12, 13, 19, and 20, with treatment 18 almost reaching significance, whereas treatments 1, 2, 3, and 6 are significantly lower. The differences due to other treatments are not significant.

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[5] The standard error of difference between treatments and general mean is computed from the formula

$$\sqrt{\left(\frac{\text{S.E. of a single plot}}{\sqrt{\text{Number of replicated plots}}}\right)^2+\left(\frac{\text{S.E. of a single plot}}{\sqrt{\text{Total number of plots}}}\right)^2}$$

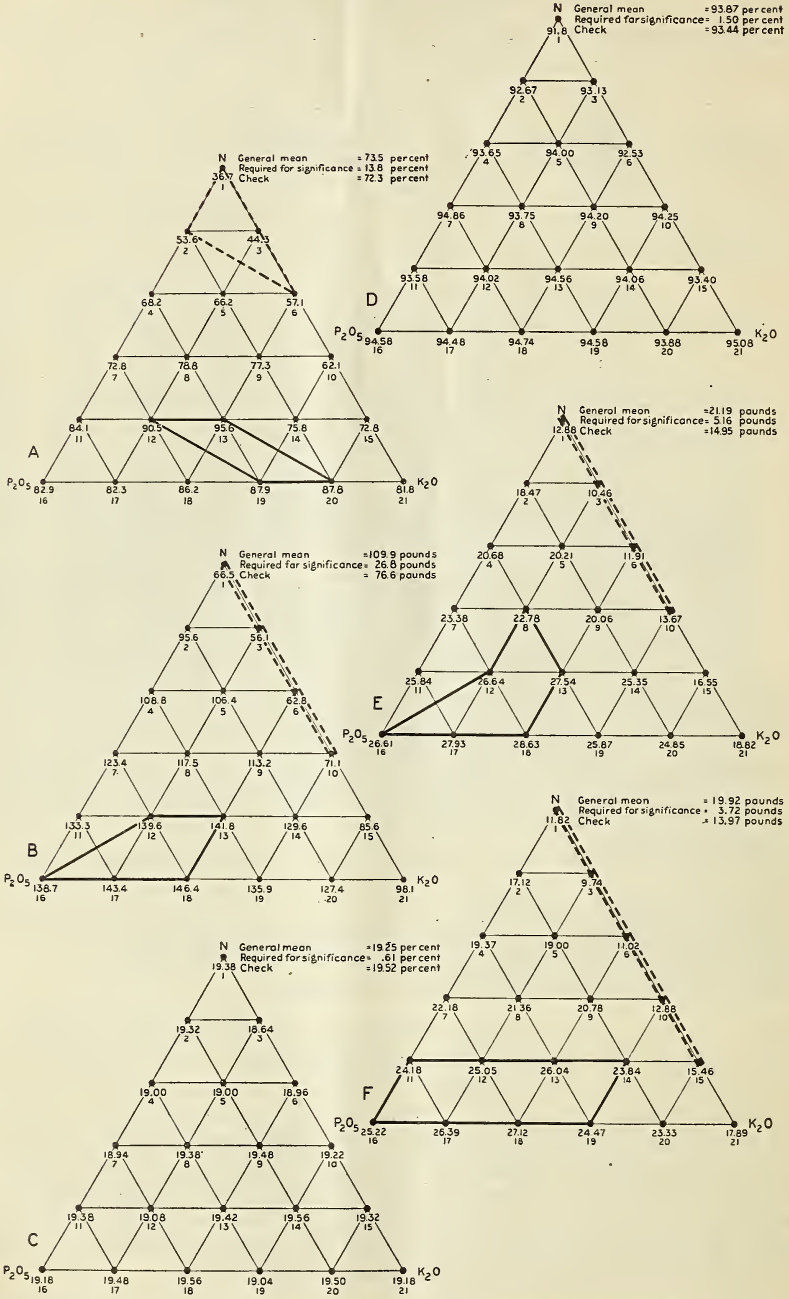

FIGURE 3.—Diagrams showing results from replicated plots in the fertilizer experiment at Castleford, Idaho, in 1931. Solid lines indicate values significantly above the general mean, broken lines indicate values below the general mean: A, Final stand; B, yield (in pounds); C, sucrose percentage; D, coefficient of apparent purity; E, gross sugar (in pounds); F, indicated-available sugar (in pounds).

It is seen that as the percentage of nitrogen increases in the fertilizer mixtures the percentage stand of sugar beets apparently decreases. In this table the treatments are also grouped so as to conform with the different percentages of fertilizer constituents used in the mixture, ranging by intervals of 4 percent from 0 percent to 20 percent.

TABLE 3.—*Effect of different proportions of nitrogen, phosphoric acid, and potash in fertilizers applied with seed of U.S. No. 1 sugar-beet variety at Castleford, Idaho, in 1931*

[Data represent averages of plots receiving similar treatment; each plot 1/61 of an acre in area and consisting of 4 rows 22 inches apart]

Plant-food constituents of fertilizer mixtures [1]		Treatment applied to plot nos. —	Final stand	Yield	Sucrose	Coefficient of apparent purity	Sugar production [2]	
							Gross	Indicated available
	Percent		*Percent*	*Pounds*	*Percent*		*Pounds*	*Pounds*
Nitrogen	0	16, 17, 18, 19, 20, 21	84.8	131.66	19.32	94.56	25.45	24.07
	4	11, 12, 13, 14, 15	87.8	126.00	19.35	93.92	24.38	22.91
	8	7, 8, 9, 10	72.8	106.33	19.26	94.27	20.47	19.30
	12	4, 5, 6	63.8	92.60	18.99	93.39	17.60	16.46
	16	2, 3	49.0	75.85	18.98	92.90	14.44	13.43
	20	1	36.7	66.48	19.38	91.80	12.88	11.82
Phosphoric acid	0	21, 15, 10, 6, 3, 1	59.1	73.39	19.12	93.67	14.05	13.13
	4	20, 14, 9, 5, 2	72.1	114.43	19.37	93.76	22.19	20.81
	8	19, 13, 8, 4	82.6	115.86	19.21	94.13	24.22	22.81
	12	18, 12, 7	82.8	135.57	19.19	94.54	26.22	24.78
	16	17, 11	83.2	138.36	19.43	94.03	26.89	25.28
	20	16	82.9	138.74	19.18	94.58	26.61	25.22
Potash	0	16, 11, 7, 4, 2, 1	66.4	110.98	19.20	93.52	21.30	19.98
	4	17, 12, 8, 5, 3	72.4	112.60	19.12	93.88	21.60	20.31
	8	18, 13, 9, 6	79.1	116.06	19.36	94.51	22.54	21.24
	12	19, 14, 10	75.3	112.20	19.27	94.30	21.63	20.40
	16	20, 15	80.3	106.53	19.41	93.64	20.70	19.40
	20	21	81.8	98.14	19.18	95.08	18.82	17.89
Complete mixtures:								
Nitrogen high	12-4-4	5	66.2	106.36	19.00	94.00	20.21	19.00
	8-8-4	8	78.8	117.54	19.38	93.75	22.78	21.36
	8-4-8	9	77.3	113.22	19.48	94.20	22.06	20.78
Average			74.1	112.37	19.29	93.98	21.68	20.38
Phosphate high	8-8-4	8	78.8	117.54	19.38	93.75	22.78	21.36
	4-12-4	12	90.5	139.62	19.08	94.02	26.64	25.05
	4-8-8	13	95.6	141.82	19.42	94.56	27.54	26.04
Average			88.3	132.99	19.29	94.11	25.65	24.15
Potash high	8-4-8	9	77.3	113.22	19.48	94.20	22.06	20.78
	4-8-8	13	95.6	141.82	19.42	94.56	27.54	26.04
	4-4-12	14	75.6	129.58	19.56	94.06	25.35	23.84
Average			82.8	128.20	19.49	94.27	24.98	23.55
Extremes of triangle:								
Nitrogen high	20-0-0	1	36.7	66.48	19.38	91.80	12.88	11.82
	16-4-0	2	53.6	95.58	19.32	92.69	18.47	17.12
	16-0-4	3	44.3	56.12	18.64	93.13	10.46	9.74
	12-8-0	4	68.2	108.84	19.00	93.65	20.68	19.37
	12-4-4	5	66.2	106.36	19.00	94.00	20.21	19.00
	12-0-8	6	57.1	62.80	18.96	92.53	11.91	11.02
Average			54.4	82.70	19.05	92.97	15.77	14.68

[1] Where 3 values are given they represent the 3 plant-food constituents, respectively, in the following order: Nitrogen, phosphoric acid, and potash.

[2] Obtained by averaging of individual plot values, whence differing slightly from product of means given in this table.

TABLE 3.—*Effect of different proportions of nitrogen, phosphoric acid, and potash in fertilizers applied with seed of U.S. No. 1 sugar-beet variety at Castleford, Idaho, in 1931*—Continued

Plant-food constituents of fertilizer mixtures		Treatment applied to plot nos.—	Final stand	Yield	Sucrose	Coefficient of apparent purity	Sugar production	
							Gross	Indicated available
Extremes of triangle—Con.	*Percent*		*Percent*	*Pounds*	*Percent*		*Pounds*	*Pounds*
Phosphate high	8–12–0	7	72.8	123.42	18.94	94.86	23.38	22.18
	4–16–0	11	84.1	133.34	19.38	93.58	25.84	24.18
	4–12–4	12	90.5	139.62	19.08	94.02	26.64	25.05
	0–20–0	16	82.9	138.74	19.18	94.58	26.61	25.22
	0–16–4	17	82.3	143.38	19.48	94.48	27.93	26.39
	0–12–8	18	86.2	146.38	19.56	94.74	28.63	27.12
Average			83.1	137.48	19.30	94.38	26.51	25.02
Potash high	8–0–12	10	62.1	71.14	19.22	94.25	13.67	12.88
	4–4–12	14	75.8	129.58	19.56	94.03	25.35	23.84
	4–0–16	15	72.8	85.64	19.32	93.90	16.55	15.46
	0–8–12	19	87.9	135.88	19.04	94.58	25.87	24.47
	0–4–16	20	87.8	127.42	19.50	93.88	24.85	23.33
	0–0–20	21	81.8	98.14	19.18	95.08	18.82	17.89
Average			78.0	107.97	19.27	94.29	20.85	19.65
Check	0–0–0		72.3	76.60	19.52	93.44	14.95	13.97
General mean			73.5	109.91	19.25	93.87	21.19	19.92
Difference required for significance			13.8	26.80	.61	1.50	5.16	3.72

There is a distinct trend in favor of the lower percentage of nitrogen in the fertilizer mixture, with the optimum point for nitrogen at about 4 percent in a 20 percent plant-food mixture. This is in accord with experimental and field results secured elsewhere (*10*).

Considering the data from the standpoint of the effect of a "complete" mixture on the stands of sugar beets, the plots fertilized with the higher percentages of phosphoric acid were apparently better balanced than the high-nitrogen plots and resulted in appreciably better stands. Plots having a high proportion of potash produced only intermediate results, with the exception of plot 13, which was high in phosphate also.

The same trends are shown when the treatments are arranged in the corresponding group under the heading Extremes of Triangle. It seems, therefore, safe to conclude that, of the mixed fertilizer combinations, the 4–12–4 mixture or one of a similar composition but probably having a still higher percentage of phosphoric acid appears the best for general use so far as stand is concerned.

YIELD

The effect of fertilizer treatment on yield of beets was very pronounced, especially in the plots fertilized with a mixture high in phosphate (table 2). Table 3 shows that results from treatments 12, 13, 16, 17, and 18 were significantly superior to the general mean (fig. 3, B). Furthermore, the results from the high-nitrogen treatments 1, 3, 6, and 10 (without phosphoric acid) were significantly lower than the general mean. It is noteworthy that two of the treatments, namely, 12 and 13, which gave results significantly superior to the general mean were treatments in which a complete fertilizer mixture high in phosphate was used.

When the treatments are grouped so as to conform to the different percentages of the fertilizer constituents used in a mixture (table 3), there is a definite decrease in yield as the percentage of nitrogen increases. When the treatments are grouped to conform to an increase in phosphoric acid, there is a steady increase in the yields of beets. The most marked difference was shown between the effect of mixtures containing no phosphate and of those containing 4 percent of phosphoric acid. With an increase in the phosphate content, the responses became less and an approximately maximum yield was obtained with 16 percent phosphate in the mixture. Sufficient potash was apparently supplied by the mixtures containing the lower percentages of potash.

With regard to the effect of complete mixtures on yield, considerable difference was found between the effect of mixtures containing a high percentage of phosphate and of those containing a high percentage of potash, and a still greater difference between the effect of the high-phosphate and that of the high-nitrogen mixtures. These differences become even more marked when the treatments are arranged as shown under the heading Extremes of Triangle, where the mixtures high in phosphate outyield by a large margin those high in potash and in nitrogen.

SUCROSE PERCENTAGE

With regard to the effect of fertilizer treatment upon sucrose percentage in the beet, the variance due to error was greater than variance due to treatment, indicating that differences in sucrose percentage were due to chance. Table 3 shows that beets from plots fertilized with complete mixtures containing the higher percentages of potash had a somewhat higher sucrose percentage, although this result must be ascribed to chance alone.

APPARENT PURITY

In coefficient of apparent purity the variance due to error was greater than variance due to treatment, indicating that differences in coefficient of apparent purity were due to chance alone. While the purity was lower in plots receiving the larger percentages of nitrogen in the fertilizer mixture, this also must be ascribed to chance and not to treatment (table 3).

SUGAR PRODUCTION

In calculated pounds of gross and indicated-available sugar per plot or acre (table 2), the results were significant according to the *z* test. In pounds of gross sugar per plot or acre (fig. 3, E, and table 3), treatments 8, 12, 13, 16, 17, and 18 gave results significantly superior to the general mean, whereas treatments 1, 3, 6, and 10 gave results significantly lower, and treatment 15 gave results almost as low. In pounds of indicated-available sugar per plot or acre (fig. 3, F, and table 3), treatments 11, 12, 13, 14, 16, 17, 18, and 19 gave results significantly higher than the general mean, and treatments 1, 3, 6, 10, and 15 gave results significantly lower than the general mean. These results were due chiefly to the phosphoric acid, which increased the yields of sugar per plot or sugar per acre in proportion as the percentage of phosphoric acid increased in the fertilizer mixture up to 16 percent, beyond which the results were practically stationary.

The complete fertilizer mixtures high in phosphate show comparatively large average values, as compared with the mixtures predominatingly high in nitrogen or potash. The same relationship holds in the groups of treatments arranged according to the high-nitrogen, high-phosphate, and high-potash fertilizer mixtures, wherein a definite trend is shown in favor of phosphoric acid.

The depressing effect of nitrogen fertilization is clearly shown in these results, the yields of sugar per plot or acre, in pounds of gross and indicated-available sugar, decreasing as the percentage of plant food derived from a nitrogenous source increased.

The results of this test indicate that fertilizers predominatingly high in phosphoric acid give the best results. The over-all increase in sugar production was due primarily to increases in beet tonnage yields.

DISCUSSION

The results of the time-of-planting experiment indicate the desirability of seasonably early plantings of the U.S. No. 1 sugar-beet variety. As the experimental field was apparently not deficient in phosphate, no advantage from application of phosphoric acid fertilizer accrued.

The very different result obtained from the intensive fertilizer test on a nearby strip of land indicates a wide divergence in soil fertility in soils which on the surface look very much alike. Such divergences are probably common in soils of this and similar areas.

In a soil lacking fertility balance, decisive results were obtained by the application of certain commercial fertilizers. These results, which have been presented in detail, are similar to those obtained with sugar beets in other western districts, notably Colorado.

Schreiner (*6*), in citing results of experimental work conducted in 1922 near Lamar, Colo., shows that phosphate applications alone produced yields of 15.2 tons of beets and 4,120 pounds of sugar per acre. Nitrogen alone produced 12 tons of beets and 2,897 pounds of sugar per acre. Where only potash was used, 10.6 tons of beets and 2,643 pounds of sugar per acre were obtained. Where phosphate, nitrogen, and potash were used in combination as a complete fertilizer, although the yield of beets was no greater than that from phosphate alone, an increase of 295 pounds of sugar per acre was obtained, whereas only 10.4 tons of beets and 2,738 pounds of sugar per acre were produced from the unfertilized plots used as checks.

Where the U.S. No. 1 variety was used, phosphate applications alone produced 11.17 tons of beets and 4,284 pounds of sugar per acre. Nitrogen alone produced 5.35 tons of beets and 2,074 pounds of sugar per acre. Where potash was used alone, 7.9 tons of beets and 3,031 pounds of sugar per acre were produced. Where phosphate, nitrogen, and potash were used in combination as a complete mixture, the yield of beets and pounds of sugar per acre were as high as those obtained from phosphate alone, whereas on the unfertilized plots used as checks, only 6.17 tons of beets and 2,407 pounds of sugar per acre were produced. While best responses were obtained under the conditions of this test from the 0–16–4 and 0–12–8 fertilizer mixtures, the difference of 0.24 tons of beets between these two treatments was not large enough to be significant. When the results from the treatments are arranged according to the high-nitrogen, high-phosphate, and high-potash groups, the trend is distinctly in favor of the high-phosphate group and in favor of the commercial-fertilizer mixtures in which phosphate predominates.

The similarity of the results in Colorado, representing several years' tests, to those obtained in 1931 in the Idaho area, in a single year's test in which the trend of results was sharply delineated, indicates that the Colorado results are generally applicable to soils in the Idaho area which have been cropped intensively or which give evidence of low fertility. For such fields, application of phosphate commercial fertilizer or of fertilizer mixtures in which phosphate predominates should in general give good results.

It is noted that these responses have been obtained with the curly-top resistant variety U.S. No. 1, shortly to be introduced for commercial use. This variety has exceeded in yield the ordinary commercial brands in this area by approximately 4½ tons of beets per acre under representative farm conditions. The results obtained in 1931 show clearly that the response of this variety can be greatly augmented under favorable cultural conditions.

SUMMARY

It is shown that under the conditions of the test reported herein the U.S. No. 1 sugar-beet variety, resistant to curly top, responded favorably to the influence of seasonably early planting.

Despite a backward season, which somewhat delayed planting operations in the Idaho area, it has been shown that of the unfertilized plots planted to the U.S. No. 1 variety those planted at an early date significantly outyielded, in tons of beets and pounds of sugar per acre, those planted at an intermediate date or later.

In another experiment, fertilizer mixtures containing high percentages of phosphoric acid produced larger yields of beets and greater yields of pounds of sugar per plot or per acre than were produced by fertilizer mixtures in which nitrogen or potash predominated.

A sharp decrease in stand of beets occurred when the percentage of nitrogen in the fertilizer mixture exceeded 8 percent. Under the conditions of this test, the trend was distinctly in favor of the lower ratio of nitrogen in the fertilizer mixture.

Considering the data as a whole under the conditions of this test, the indications are that a mixture in which the percentage of phosphoric acid predominates is likely to produce consistently good results with sugar beets, especially under cropping and soil conditions that necessitate the use of commercial fertilizers.

Attention is called to the fact that these favoring practices, namely, seasonably early planting and applications of a suitable commercial fertilizer, will increase the advantages of using the curly-top resistant variety U.S. No. 1.

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